Weatherwise

Volume 7, Number 2 April 1954

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Editor: **18 March 1954**

Rogers Pass, Montana, minimum thermometer test complete. New record six nine point seven degrees below zero. R. E. Spencer, USWB, Wash., D.C.

8 March 1954

Editor:

This letter will confirm the record-setting minimum of − 68° observed at Rogers Pass, Montana the morning of January 20, 1954. We have forwarded two thermometers used in obtaining this reading to the Weather Bureau Instrument Division in Washington for checking, but as yet we have had no report on the results of this check.

In array checks at the Weather Records Processing Center and such review as we were able to give the reading in the Section Center, − 68° appears to be a good one. The fact that the reading was below the bottom mark on our minimum thermometer, plus the fact that a current reading of − 68° was noted on the observer's own high-grade private instrument leads us to believe that there may be a degree or two correction—either higher or lower—when the results of our Instrument Division check are available. Our publishing of that reading in Climatological Data is being accompanied by a note indicating that it is subject to revision.

Rogers Pass is located airline less than ½ mile from the summit of the Continental Divide at an elevation of 5470 feet. It is located in a saucer-like depression on the west slope, and at the time the reading was made there were several feet of snow on the ground.

WILBUR F. MCKINNEY
USWB, Helena, Montana

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Cover: Damage sustained by the forward surfaces of a DC-4 aircraft after an encounter with severe hail near Pueblo, Colo., on 27 June 1951. Braniff Airline photo.

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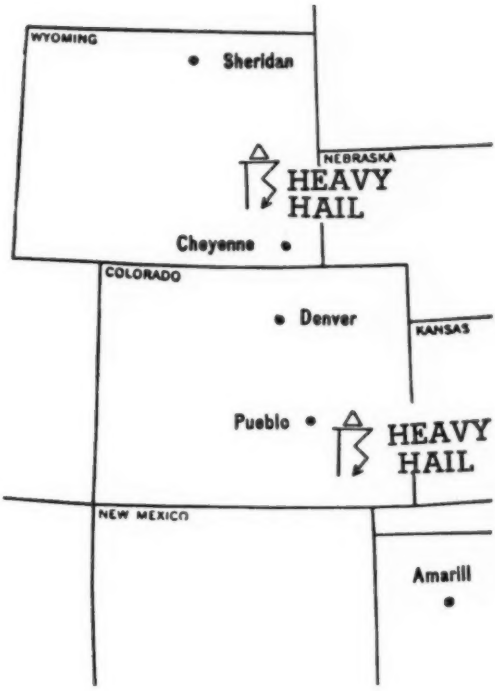


Aircraft Encounters with Severe Hailstorms

H. B. LAIRD, *U. S. Weather Bureau, Denver, Colorado*

WITH the increase in speed and all-weather capabilities of modern aircraft, the potential hazards to equipment and passenger safety from severe hail in flight become of increasingly major concern to commercial aviation. The following account describes two sudden encounters with very severe hail experienced by two commercial airliners along the eastern slopes of the Rockies.

On the afternoon of 20 May 1948 a regularly scheduled Western Air Lines flight, using a Douglas DC-3 aircraft, took off at Sheridan, Wyoming, en route to Denver, Colorado. Just north of Cheyenne, Wyoming, a severe hailstorm was encountered, of such severity that it broke the windshields, shredded the ailerons and elevators, and did major structural damage to the fuselage and wings. An emergency landing was made at Cheyenne, so that passengers could be transferred to another aircraft for the remainder of the flight. Details of the encounter were related to the writer by Captain Harold Wynne, the pilot.

The flight had paralleled a line of active, growing thunderstorms from a point just north of Casper, Wyoming. A regular stop was made there, and the captain received a report of hail to the south along the route near Diamond. Since the flight was about an hour's flying time north of the reported hail zone, the captain believed that the storm would pass to the east and decided to proceed.

The schedule was such that Cheyenne, just beyond Diamond, would be reached soon after dark. After climbing to an altitude of 10,000 feet, a southerly course was taken along the upwind side of a line of thunderstorms, between the clouds to the east and the mountains to the west. The thunderstorms appeared to be moving eastward, but near Wheatland they began to build to the west of the course also, with sharp lightning on the mountains. It was dusk by this time, and the beacons on the course ahead to the south were plainly visible. As the flight approached Diamond, the tail end of a shower appeared to be trailing across the course with

the main center farther eastward, and there was still lightning to the west.

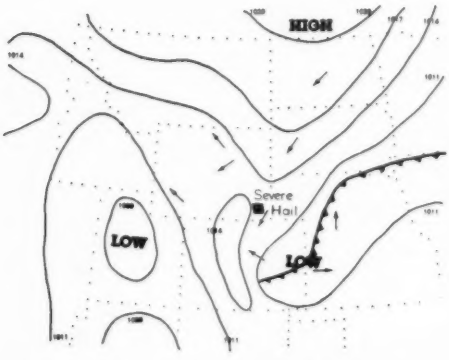
About one minute north of Diamond the flight met Western's northbound trip, and learned that their ship had been beneath a squall at 7,500 feet and had encountered a few hailstones. The beacons were still visible from 10,000 feet, but the captain proceeded immediately to let down to 8,000 feet and to reduce speed. The hail struck just as the new level was reached, and at the same time the beacon lights disappeared from view. An immediate 30-degree bank left turn was started. By the time the aircraft was headed northeast, a period of 45 seconds having elapsed, all the damage had been done. A further 45-degree turn toward the east brought the ship into the clear in two minutes.

Neither pilot nor co-pilot was injured, although one large stone crashed through the windshield, flew past the pilots, and struck the bulkhead. The pilots checked the aircraft's stability as they felt sure there was damage to the control surfaces, but tests found them still effective. The flight proceeded immediately on into Cheyenne, and transferred the passengers to another ship. Pictures were taken of the aircraft before it was ferried to Los Angeles for a major overhaul. There were dents in the nose of the ship as large as a man's head, suggesting that the stones were so concentrated in spots as to give the effect of individually much larger stones. Both wings sustained major structural damage and were considered beyond repair. The elevators were shredded with holes up to three to four inches across and 14 inches long. The windshield was shattered. The right wing was in worse condition than the left, indicating the localized nature of the storm and the sharp gradient of hail intensity.

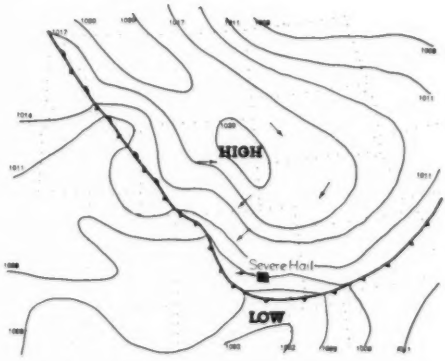
On the next day's trip another pilot noted an oval area of hail still on the ground in the vicinity of Diamond. Reports from the area told of hail drifted along the highway to a depth of three feet. It was the captain's opinion that the storm concentrated all its hail in one place. Had it been daylight, the storm would have looked much worse, he thought, and he would have been able to take measures to avoid it. The flight was made underneath the level of the cloud bases, and, aside from light turbulence, nothing was encountered either in or out of the storm to give warning of such intense activity.

Although thunderstorms and hailstorms in the Wyoming-Colorado area are not rare, a storm of this intensity is not a common occurrence. To produce a hailstorm of such severity, there must be a combination of several factors, as the atmospheric conditions at the time of this storm and during the day preceding illustrate.

At 0530 MST a weak surface cold front, which had moved from Montana, was near Cheyenne; it continued southward during the day, and at 2030, approximately the time of the storm, was near Pueblo, some 200 miles farther south. The surface map for 1730 MST and the 7,000 foot winds aloft are shown on an accompanying chart. The top of the frontal layer in southeastern Wyoming was



Surface chart for 1730 MST, 20 May 1948.



Surface chart for 1730 MST, 27 June 1951.

Damage to the wing and airleron of a DC-4 from a hail encounter.

at 8,000 feet at 2000, as shown by the Rapid City and Lander soundings. Winds from the ground level up to the frontal surface in the Scottsbluff-Cheyenne area were northeast 15 to 30 mph throughout the day. Beneath the frontal surface a relative humidity of 65 to 90 per cent existed; above the frontal surface humidities were 35–55 per cent at Rapid City, but very dry, around 10 per cent, at Lander. One can disregard the Rapid City sounding here because the wind flow at upper levels was light southwesterly. At the 10,000 foot level a cold low was centered in northern California with the coldest temperature at − 8° C. above Sacramento, and a warm high covered the southern Plains with the warmest air + 10° C. at Rapid City. The southerly circulation at 10,000 feet around the coastal low was bounded on the east by the Continental Divide. Above 10,000 feet the air was very dry as mentioned before, and winds were southerly about 15 mph in the Cheyenne area. The lapse rate at Lander was very nearly dry adiabatic from 10,000 to 20,000 feet and only slightly less unstable up to 25,000 feet.

Some showers and thunderstorms had occurred in Montana during the preceding night, and there were a few light showers in northeastern Wyoming that morning. The clouds became mostly scattered during the morning to permit plenty of sunshine, and temperatures warmed to near 80° F. throughout eastern Wyoming by noon.

Many thunderstorms with hail occur in this area each summer, but the report of the air encounter, together with ground reports which followed the next day, indicates that this was one of the most severe in recent times.

On 27 June 1951 a Braniff International Airways DC-4 departed from Dallas on the regularly scheduled evening flight to Denver. In the vicinity of Pueblo, a thunder and hailstorm was encountered which did damage comparable to the Cheyenne storm and in a much shorter time.

At 2118 MST the flight left Amarillo on a course direct to Colorado Springs. As the flight approached the vicinity of Pueblo, thunderstorm activity was noted to the right of the course ahead, the center appearing to be about 50 miles southeast of Pueblo. The "on course" took the flight about 15 miles east of Pueblo. Just before the hail struck the flight was between layers on instrument flight rules, and the first beacon south of Pueblo was visible off to the left from the altitude of 10,000 feet. As the flight came to a point about 15 miles east-southeast of Pueblo, the hail struck without any previous warning in the form of turbulence or scattered stones.

Both windshields were instantly broken, and the pilots found that the crash panels were necessary. The actual encounter with the hail was very brief, estimated by both the captain and first officer as about three to five seconds! The hail was followed immediately by severe turbulence for a period of about three minutes, then the air became smooth, and the flight proceeded on to Colorado Springs for a landing at 2256 MST.

Upon inspection immediately after landing, the captain decided to cancel the remainder of the flight. Damage to the aircraft was described by company officials as "extensive." Large holes were torn in the ailerons and elevators. Dents as large as a man's head were

made in the nose of the fuselage and slightly smaller ones in the cowling of the engines on the left side. The leading edges of both wings were severely dented, and rips showed in the de-icing boots.

Although estimates or measurements of stone sizes are not available, it would require extremely severe hail, with large and numerous stones, to do so much damage in so short a time. Using approximations of an airspeed of 200 mph or 17,600 feet per minute and an elapsed time of four seconds or 1/15 of a minute, the width of the storm measured about 1,200 feet, a rather narrow shaft of hail.

No later evidence of this storm was available at either Pueblo or Fowler, the nearest reporting weather stations, nor were any reports received from ground observers in the sparsely populated area. Pueblo received about 0.25 inch of rain, Fowler about 0.50.

The upper level low was centered in southern Canada just north of North Dakota. The coldest air at about 10,000 feet was just southwest of the surface low center in extreme northern Montana and southern Alberta.

A surface cold front, which was in the Casper-Scottsbluff area at 0530 on the 27th, moved southward, and was just approaching Pueblo at 1730. Showers had occurred in the Rapid City-Moorcroft-Sheridan area during the morning behind the front. By 1730 with the front approaching Pueblo, there were showers in the Colorado Springs area, a thunderstorm at Limon, about 80 miles northeast of Pueblo, and heavy and swelling cumulus clouds throughout eastern Colorado.

The Lowry Field, Denver, sounding at 0800 and again at 1400 showed dry air ahead of the front with relative humidities about 20 per cent. By inspection of the Lowry radiosonde for the following morning, it appears that the moisture had increased considerably to raise the relative humidity, even with surface temperatures in the upper 80's, to about 50 per cent. By 2330 at Pueblo a surface temperature of 65° was accompanied by a relative humidity of near 70 per cent. The Lowry 1400 sounding showed also that the air was extremely unstable to 20,000 feet.

Beneath the frontal surface lower level winds at 2000 became easterly 20 to 25 knots, advecting moisture rapidly into the Pueblo area. The station elevation of Pueblo is 4,700 feet while at Garden City, 200 miles to the east, the elevation is 2,800 feet; there was an orographic lift of about 2,000 feet in the direction of the lower level winds.

In summary, the reviews of these two situations illustrate their similarities: (1) In each case there was a sharp front with moist air behind it moving into the area from the northeast beneath a very dry layer aloft. (2) Added to the frontal lift was the orographic effect of the slope up which the surface and lower layer winds were blowing. The surface elevation at Rapid City is 3,900

(Continued on page 40)

A "pointing finger" of hail as shown by an airborne radar scope on 28 July 1953 at 9,300 ft. msl. near Cheyenne, Wyoming. Courtesy United Airlines.

Heavy hail makes a characteristic configuration on airborne radar scope on 18 August 1953 at 8,900 ft. msl. near Byers, Colo. Courtesy United Airlines.

Radar Detection of Tornadoes

A Statement by the

American Meteorological Society Committee on Radar Meteorology

In the year 1953, an unusually large number of destructive tornadoes swept through many states from Texas to New Hampshire. For the first time a few of these (ten or more) occurred under radar observation. Because of the exceptional destruction and because radar records are now available, a wide scientific and popular interest has developed in the use of radar for tornado warnings. Certain types of radars clearly can improve the effectiveness of any tornado warning procedure, but no one should assume that even the best of our storm detection radars can at present pinpoint a tornado and positively identify it as such.

In regions where tornadoes are frequent, warning services have been organized and plans laid to supplement basic tornado forecasts with radar observations. It is important then to emphasize that radar's prime function in these services will be to locate, as early as possible, not the tornadoes themselves, but those thunderstorms within the tornado danger area which are approaching tornado-spawning proportions.

While radar location of the tornado itself cannot as yet be relied upon, several approaches offer promise. In some cases distinctively shaped echoes have been observed coming from the tornado and its immediate vicinity. Such echoes have been noted to have reflectivity approaching that of the associated thunderstorm but with direction of motion differing from that of the other echoes of the squall line. Further observations are needed to test the reliability of these characteristics. There are other possibilities. Radar echoes from all storms display phase and intensity variations which are a function of the velocities of the particles within the storm. It seems probable, then, that these variations could indicate the high velocities in tornadoes. These characteristics should be studied at the first opportunity, as should other possibilities such as the use of radar wave lengths longer than 10 cm.

Many operational problems must be examined such as the maximum working range of a radar in this application. (The tornadoes observed by radar in 1953 were all within 100 miles.) While radar can play an important role in tornado warning networks in 1954, only further study will develop its full potentialities. Research into these potentialities will not only improve its dependability, but should also teach us much about the nature of the tornadoes themselves. It is to be hoped that all operational radars in the United States (particularly the Air Defense network) will be mobilized against these havoc-wreaking storms.

There is another electrical method of storm-tracking, called SFERICS, which is older than radar. It consists of radio direction finding on the "static" produced by the storm plus a study of the character of that "static." This method has been applied to tornado identification for two years or more and shows considerable promise. It may even distinguish those storms that are about to spawn tornadoes. The techniques of radar, on the one hand, and of sferics on the other, seem to complement each other. The greatest hope, both for the immediate future and for long-term plans, would seem to lie in the combined operation of both techniques.

J. S. MARSHALL, *Chairman*

January 25, 1954

Texas Radar Net

Suspicious looking clouds and thunderstorms in Texas and vicinity will be kept under constant surveillance this spring and summer by a net of radar stations that will cover the entire state. The project is under the sponsorship of the Texas A & M College Foundation. Installations will be at first-order Weather Bureau stations where personnel is available to man the scopes during threatening weather. The average cost of modification and installation is $10,000; this expense is borne by the municipality whose citizens will benefit from the warning system. Fourteen stations are now preparing to operate and six more are planned. The maximum range of the sets is 200 miles.

The Eclipse of 9 July 1945. Courtesy Sky & Telescope.

The Weather Outlook for This Year's Eclipse

EDWARD M. BROOKS, *Institute of Technology, St. Louis University*

NO meteorologist can give a reliable forecast of the weather for the eclipse on 30 June 1954, until a few days before that date. But astronomers will not wait for this forecast, as they are already selecting their observation points, and planning to set up their equipment weeks before the eclipse. Consequently, for weather information, they must rely on the records of past weather along the eclipse path. The purpose of this paper is to compare the chances of observing the eclipse at different places in the United States and Canada, along the most accessible portions of the path of totality.

A first estimate of sky conditions might be based on the average cloudiness for June and July (a month either side of the eclipse date) already available in published climatological summaries. Both June and July average cloudiness maps (from Sir Napier Shaw's *Manual of Meteorology*, Vol. II, pages 158, 160) show values increasing northeastward from less than 0.5 cloudiness at the beginning of the eclipse path in northeastern Nebraska to more than 0.7 cloudiness on the Labrador coast.

This is useful information, but is not sufficiently refined, for the averages are for the entire day rather than for 5 a.m. CST, the approximate time of the total eclipse, and there is no differentiation between clouds of different thicknesses. The necessary refinements were made by tabulating weather reports from daily weather maps for 6:30 a.m. CST on five Junes (1949–1953) and six Julys (1948–1953). The four weather stations in the United States and the three in Canada within or near the eclipse path that were selected for the tabulation are Spencer, Iowa; Minneapolis, Minn.; Park Falls, Wis.; Calumet, Mich.; White River, Ont.; Kapuskasing, Ont.; and Moosonee, Ont.

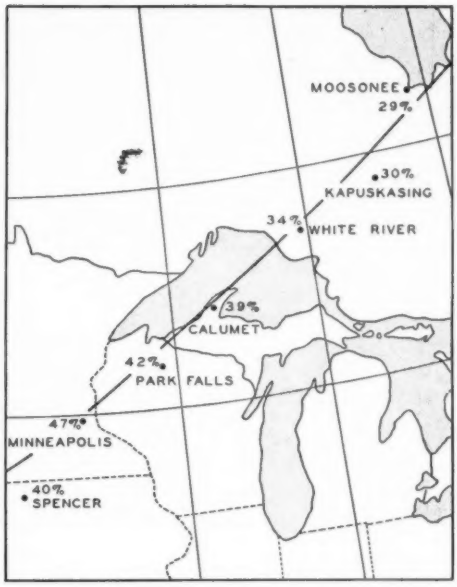
For each day's 6:30 a.m. observation, a decision was made as to whether or not an eclipse could have been seen if it had occurred. This decision was based on cloudiness, visibility, and precipitation. It was assumed that the eclipse could be seen through clouds only if they were thin and not continuous, which is usually the case for high clouds, but not for middle or low clouds. The cloudiness criteria for success were that high clouds did not cover the whole sky, middle clouds did not cover more than 3/10 of the sky, and low clouds did not cover more than 1/10 of the sky. If the 6:30 a.m. report said that the cloudiness was increasing, more tolerance in these criteria was allowed, and if the cloudiness was reported as decreasing, less tolerance was allowed, because the observation was 1½ hours after the time of the hypothetical eclipse. Visibility was considered important because of the low altitude of the sun above the horizon at 5 a.m. Successful observing was assumed only if there was no haze at 6:30 a.m. and if within the previous six hours due to radiational cooling there had been no fog. Also, observing was called successful only if no rain or thunder had occurred during the previous four hours (2:30–6:30 a.m.).

The accompanying figure shows the results, which generally confirm the increase of average cloudiness, or decrease of visibility, to-

ward the northeast along the eclipse path. Minneapolis, with 47 per cent successful observing, proved best, having 156 acceptable days, or nearly half of the 334 days tabulated. Park Falls, in second place with 42 per cent seeing, was better than Spencer, in third place with 40 per cent. The conditions deteriorated progressively to the James Bay region, where Moosonee, with 29 per cent, had only 92 good days, or slightly more than one quarter of 319 days.

The criteria of the analysis for visual observations of the eclipse are not restrictive enough for instrumental observations. For astronomical photography, a new set of necessary conditions was chosen. The sky should be completely clear, the relative humidity should be as low as possible, and the sun and moon should have an altitude of more than five degrees above the horizon. A tabulation of the number of mornings without clouds, fog, or haze gave the results listed in the last column of the table. Park Falls had 78 perfect days, or nearly one quarter of 320 days. Minneapolis, with only 12 per cent, had only half as many perfect days, 41 of 334. Minneapolis and Spencer are judged unsuitable, however, because of the low solar altitudes of about 5° and 3°, respectively, at eclipse time.

As no observation points other than Park Falls and Spencer had over 15 per cent perfect days, the odds appear poor for observations from Michigan northeastward, where the higher altitudes of the sun and moon may be useless because the sun is so often hidden behind clouds. Park Falls is also favored by an average relative humidity at 6:30 a.m. in June and July of 82 per cent, which is slightly lower than at some of the other stations. The



The path of the center of totality of the early morning eclipse on 30 June 1954 and the percentage chance that the eclipse will be visible.

effect of Lake Superior on the relative humidity on summer mornings is slight because at that time the temperature of the water is nearly the same as the temperature of the surrounding land.

In conclusion, Minneapolis looks best for visual observations because the sky is less often overcast and the air is relatively dry. On an average morning, the eclipse should be visible through scattered clouds. On the other hand, Park Falls may offer the best op-

(*Continued on page 40*)

Weather Station	*Elevation in feet*	*Altitude of sun and moon*	*Average relative humidity*	*Chance that eclipse will be visible*	*Chance for no clouds, fog, or haze*
Spencer, Iowa	1,339	3°	86%	40%	18%
Minneapolis, Minn.	838	5°	81%	47%	12%
Park Falls, Wis.	1,539	7°	82%	42%	24%
Calumet, Mich.	1,240	9°	83%	39%	15%
White River, Ont.	1,243	12°	88%	34%	14%
Kapuskasing, Ont.	752	14°	86%	30%	10%
Moosonee, Ont.	34	16°	80%	29%	9%

The wave-cloud formation at Denver as photographed by Paul E. Branstine at 1735 MST, 14 February 1953. Camera is headed west toward Rockies; cloud formation is moving south about over Park of Red Rocks.

Wave-Cloud Formation at Denver

AN interesting eye-witness account and a unique photograph of a remarkable cloud formation has been received from Mr. K. C. Tillotson, U. S. Weather Bureau, Denver, Colorado.

"A very unusual cloud formation was observed at Denver, Colorado on February 14, 1953. It was a long pencil-like cloud which appeared to be oriented nearly north-south between the eastern part of the city and the Rockies, which lie approximately thirty miles to the west. Two snapshots were taken by Mr. Paul E. Branstine, who lives just outside the southeastern part of the city. It was observed by three Weather Bureau personnel as well. The photograph was taken looking westward towards the mountains at 1735 MST. The formation was moving rapidly southward along the foothills at the time the picture was taken and was judged to be located over or very near the foothills. It broke up very quickly and the cloud continued to travel south. It was likely very nearly over the Park of the Red Rocks at the moment the picture was taken.

"All who observed the cloud agreed that it lasted only a very few minutes. It is apparent that the amplitude of the waves was nearly as great as the individual wave length itself. Extremely unstable waves of this nature could be expected to last only a very short time. At the time of the photograph the waves were already in the breaking stage. The sky condition at the 1728 MST observation was reported as 0/10 stratocumulus at 6,000 feet and 0/10 altocumulus estimated at 14,000 feet above the ground (or less than 1/10 sky coverage), with the altocumulus moving from the northwest. Difficulty is experienced, however, in estimating the height of a cloud covering such a small part of the sky. The elevation of Denver is approximately 5,300 feet.

"Upon investigation, it was found that a pronounced jet stream was located over this region with an orientation of approximately 340 degrees, or about the same as the major axis of the cloud. . . .

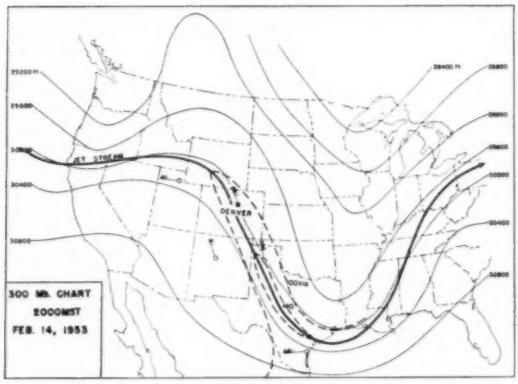
"An analysis of the raobs and the constant pressure charts prepared from the usual trans-

mitted data indicated rather rapid temperature changes in the atmosphere were taking place. This (Denver) area was on the western side of a rather large scale trough at the 500 and 300 mb levels. There was a pronounced jet flow on the western side of the trough with the jet maximum at 300 mb, approximately 30,000 ft., apparently right over the Denver area that day. . . .

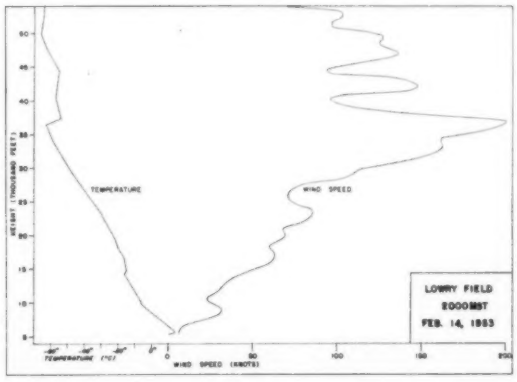
"Since the processes producing this cloud phenomena were taking place in a very small area, it is virtually impossible to measure the conditions which were present at that very time. Summarizing what little information is at hand, it appears that the combination of rather marked temperature advection, sufficient moisture content for condensation, and a rather sharp wind shear was responsible for this unusual set of breaking atmospheric waves."

A subsequent analysis of the original records from Lowry Field indicates that the maximum wind speed increased from a value of 78 knots on the 0200 MST sounding to 200 knots on the 2000 MST sounding with a corresponding increase in the vertical wind shear at all levels. The vertical profiles of the temperature and the wind speed at 2000 MST are shown. This figure indicates high wind speed and considerable vertical wind shear as indicated by Mr. Tillotson.

DeVer Colson
USWB, Wash., D. C.



The pressure contours at approximately 30,000 feet. Solid line is jet stream which passes just west of the wave-cloud scene.



The profile of the upper-air winds and temperatures after the wave-cloud dissipated as shown by the Lowry Air Force Base sounding.

The A. M. S. Starts a Busy Year

The 127th National Meeting in New York City on 25–28 January 1954 marked the commencement of the 36th year of the American Meteorological Society's active history. During the present year six more national meetings have been scheduled with one special symposium also planned. The 128th National Meeting will take place at Baltimore, Maryland, on 28–30 April under the sponsorship of the Baltimore seminar of the AMS. All sessions will be held at the Lord Baltimore hotel in downtown Baltimore. The main feature of the meeting will be a dinner on Thursday evening, 29 April.

Technical sessions have been scheduled on the following subjects: Meteorological measurements, radiation, general circulation, general meteorology, turbulence, synoptic meteorology, and climatology. Two main features are also on the program: a discussion

sy Year with New York Meeting

of the World Meteorological Organization and world meteorology and a symposium on the interaction of the sea and the atmosphere.

Members and their friends who plan to attend are urged to make immediate reservations directly with the Lord Baltimore. The full program will appear in the next issue of the *Bulletin of the AMS* which is now in the press.

Calendar of Meetings—1954

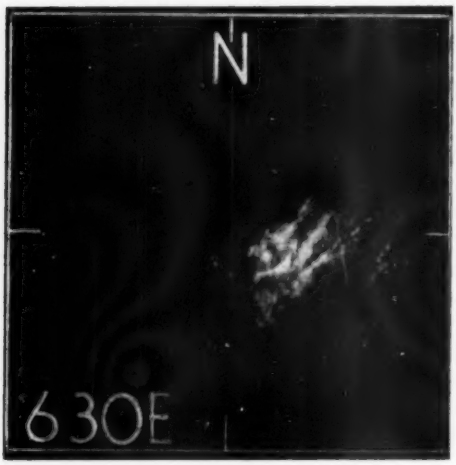
Baltimore	28–30 April
Pullman, Wash.	23–24 June
Rochester, N. Y.	24–25 August
Columbus, Ohio	21–23 September
Miami, Fla.	16–18 November
Berkeley, Cal.	28–30 December

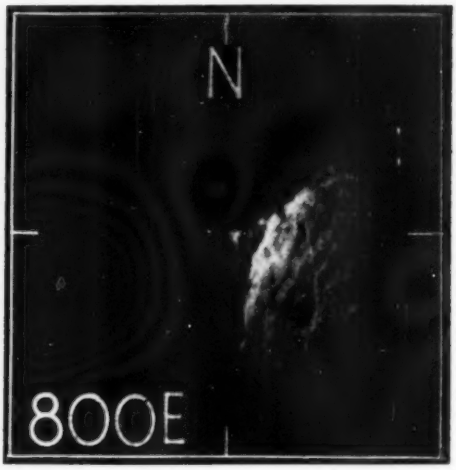
Simple Radar Scope Photography

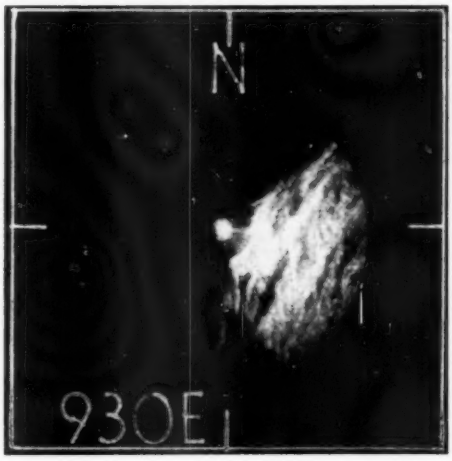
MARVIN N. HUNTER,
U. S. Weather Bureau,
National Airport, Washington, D. C.

THE use of radar as a weather observing instrument has become increasingly important during the past several years. This device has expanded the range of "vision" of the weather observer from a few miles up to 100 miles, and even to 200 miles or more with special equipment. It has not only been useful in observing the birth, growth, development, and movement of storms, but it has also been a valuable educational tool to the meteorologist. Occasionally, echoes of an unusual nature are observed on the screen of the radar. The variations that make these echoes unusual may be in either the intensity of the echoes or the peculiar configuration of the echoes on the screen. A permanent record of such echoes may not only be of interest, but it may also be of some aid in understanding some of the physical processes involved in weather.

Photography offers a means of preserving such records, but it is usually somewhat involved. The expensive automatic radar cameras, which are often attached to the radar

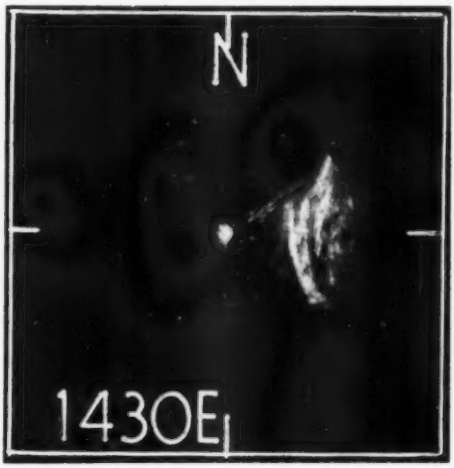






screen where only one screen is available, usually interfere with the actual observing of the radar screen for use in formulating operational advice. Many photographs of echoes associated with fronts, squall lines, thunderstorms, hurricanes, and even tornadoes have been made. Now when rather rare weather events occur, a record such as a photograph must be made on the spot without delay, if a visual likeness of the echo is to be preserved for future reference. Not all radar stations have the photographic equipment that is ordinarily used to make such records.

Photographs of radar echoes can be made with very inexpensive equipment by use of a simple technique. The passage of "Hurricane Barbara" northward along the coast of Virginia and Maryland on 14 August 1953 offered an opportunity to take such pictures. A Brownie Target Six-16 box type camera with a fixed focus using Super XX film was the basic equipment used. A Kodak portrait lens with a focal length of 42 inches was attached to the front of the camera by means of scotch tape. The camera cost less than $10.00 and the lens $1.72. A step ladder was set up at a distance of about three feet from the front of the radar screen. The camera was placed on the step ladder so that the center of the radar screen and the height of the



camera were about the same. Then the camera was pointed toward the radar screen and a time exposure of ten seconds was made. The length of the exposure was equal to the time that it took for the sweep on the radar screen to make one complete revolution.

An exposure was made every 30 minutes, plus or minus three minutes, from 0600 EST through 1500 EST on 14 August 1953. The exposure at 0900 produced a blank which was probably the result of not having the exposure control mechanism properly set. Each of the other exposures showed a reasonable facsimile of the observed echoes.

The radar from which these photographs were made is the MEW type with a range of 100 miles. The photographs include the entire face of the scope, and the center of the photographs represents the location of the radar station at Washington National Airport. The concentric circles which show on many of the photographs are range markers and the interval between each marker represents ten miles. Aircraft echoes appear as small dots. The azimuth angle is measured clockwise from the north which has been marked at the top of each photograph.

The first photograph was taken after rain had already begun in the Washington area and while the center of the hurricane was located a short distance east-southeast of Norfolk, Virginia. Thereafter the intensity of the precipitation diminished slightly, as shown by the echoes at the time of the observation, and the photographs indicate this. Later, as precipitation increased, the well-known banded structure of the echoes became more evident. There is some evidence of less intense precipitation along the outer periphery of the photographs as the hurricane center moved up the coast at a distance of about 25 miles beyond the range of the radar. As the hurricane moved further out to sea, the precipitation area retreated as shown in the last few photographs.

It is thought that some of the meteorologists who have access to radars might be interested in photographing radar echoes using inexpensive equipment and a simple technique somewhat like that which is described above. Worthwhile records can be obtained by little more than "pointing the camera and shooting."

Eclipse (*Continued from page 33*)

portunity for work with astronomical instruments, because whenever the sky clears, it is likely to clear up completely in the dry air of high-pressure areas between storms.

These suggestions based on climatological statistics are offered to help observers take into account weather conditions. At best, it will be a gamble to find the right spot to see and observe the eclipse because none of the chances for success runs over 50 per cent. Perhaps the answer is to fly an airplane above any low clouds that may be present.

My personal plan is to locate in the northeastern part of St. Paul to get a view of the sun and moon away from the city smoke of St. Paul and Minneapolis to the west. If a storm center is moving into the Dakotas on eclipse day, a last-minute shift of location to Wisconsin will be made.

Hailstorms (*Continued from page 30*)

feet; at Cheyenne, in direct line with the lower level windflow, the elevation is 6,100 feet. A similar difference exists between Garden City and Pueblo. (3) The steep lapse rate above the frontal surface helped to continue the instability to high levels. (4) Dry air aloft added to the instability. (5) Much sunshine throughout a large part of the day allowed for continued convective activity. The chief difference lay in the pressure pattern and the direction of the cold air source.

Eclipse Weather Broadcasts

Radio weather broadcasts from the Weather Bureau Airport Station at Minneapolis are being planned for the evening of 29 June and the very early hours of 30 June 1954, just before the total eclipse of the sun in this area. In addition to a forecast of expected weather conditions at dawn for numerous key locations along and near the path of totality in southern Minnesota and northern Wisconsin, we intend also to give a little story on the eclipse itself, its duration, width of its path, and other pertinent material.

Our regular weather broadcasts, heard on WMIN, Twin Cities, at 5:30 p.m. and on WCCO, Minneapolis, at 6:00 p.m. of the

29th will contain a preliminary forecast, but these will present other routine weather information besides. A special broadcast at 11:05 p.m. over three Twin Cities' stations simultaneously—WCCO (830 kcs), WMIN (1400 kcs, FM 99.5 mcs) and WDGY (1130 kcs) will be considered our principal eclipse weather round-up. Because WMIN is on the air several hours after midnight, we shall present one additional broadcast at 2:00 a.m. on the 30th, on that station.

If any amateur weathermen in this area would like to contribute to our reporting network that night, they may reach us by calling either our Minneapolis phone, DUpont 7182 or our St. Paul number, NEstor 5421.

Weather Ships

The United States and fourteen other nations signed an agreement 11 February to continue the North Atlantic weather station network but on a reduced basis. One station of the ten currently operated will be eliminated—station "How" located 350 miles off the Virginia coast on the route to Bermuda.

The agreement, by member nations of the International Civil Aviation Organization, a United Nations agency, cut the number of stations operated by the United States from five to four and the number of ships provided by the United States to man these stations from fourteen to eleven.

Five European states that actively participate in the operations, Britain, France, Norway, Sweden and the Netherlands, will continue to man five stations, with a total of ten vessels. The nine other countries that signed the agreement are beneficiaries and share the costs. The two-year accord will become effective 1 July when the present arrangement expires.

It was felt that a readjustment of the responsibilities should be made on the basis of aeronautical benefits and non-aeronautical benefits. Aeronautical benefits were considered to represent 80 per cent of the value of the program and were based on the number of crossings made by aircraft of each participating nation. Non-aeronautical benefits were judged to represent 20 per cent and resulted mainly from assistance in weather forecasting for the nations surrounding the North Atlantic.

The U. S. Weather Bureau is doing a considerable amount of research to learn as much as possible about tornadoes, severe thunderstorms, hail, and local windstorms. This year a greater effort than ever will be made to collect reliable information from all possible sources concerning the occurrence and exact nature of severe local storms. Amateur weathermen throughout America can be of great assistance in this program. First-hand observations of the following kinds of local storms are needed:

1. Tornadoes.
2. Severe local thunderstorms.
3. Severe local windstorms.
4. Hailstones more than one-half inch in diameter.

If you observe any such local storms, the following information covering *each* case will be useful:

1. Date and time of beginning and ending of storm.
2. Location of the storm and direction of movement.
3. Area covered by the storm (width and length of storm path).
4. Description of the clouds observed.
5. In tornado cases, did you observe a funnel or funnels, and did it (or they) touch the ground?
6. What kind of damage did the storm cause?
7. Were there personal injuries or deaths?

Send your notes, with your name and address included, to:

U. S. Weather Bureau
Climatological Services Division
Washington 25, D. C.

Weatherwatch

A Warm Winter Brings Record Low Temperature!

DAVID M. LUDLUM, *Editor*

ANOTHER winter has gone into the record books. It will be remembered as a supreme example of the vagaries for which the North American climate is noted. Though it was a very warm season across the nation from December through February, one of the most prolonged and severe spells of continuous below zero temperatures in the past century occurred during an interlude in the middle of January, and the lowest official thermometer reading ever reported in the United States was noted in Montana during this period. A few days later, however, the mercury climbed to all-time high marks for February at many points in the northern Plains!

The winter of 1953–54 continued the series of mild winters that have prevailed since the 1951–52 season. Only isolated points in California and in the Georgia–Florida area had below normal figures for the three-month season of 1953–54, and the departures below normal were insignificant. It was very warm in a broad band across the northern states from Idaho–Wyoming–Montana to Lake Michigan; departures above normal were plus seven degrees in Montana and plus six in Wisconsin. Another warm center was in northern New England where the figures averaged about five degrees above normal. There were two periods of real winter frigidity: one of 15 days duration in middle and late January, and one of three days in the middle of February. Otherwise, mild Pacific air dominated the weather across the country.

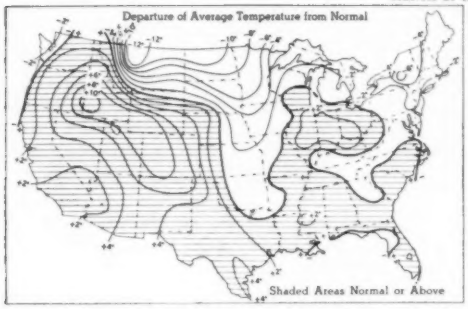
As can be expected with a warm weather pattern, precipitation was generally deficient, and the long-continued dry period in central sections again threatened to aggravate the water shortage into a major crisis—in both the Middle West where ground water was markedly deficient and in the winter wheat areas of the central and southern Plains where the drought had seriously affected crops during the past two growing seasons.

THE CIRCULATION—The general atmospheric circulation features in the United States, as shown by the mean maps of upper-air flow, were devoid of unusual features. In general, a rather flat pattern of west-east movement prevailed with a relatively rapid westerly flow in the U. S. Further north, however, over Canada contour lines of air flow had a different orientation. Pressure averaged low over northeastern Canada and high over Alaska and the Bering Sea area, from whence surface anticyclones moved southeastward in the prevailing flow to bring arctic influences to the northern border states. But the fast westerlies across the United States did not permit the northwest flow to penetrate very far south, so the areas of severe cold were mainly confined to northern border sections.

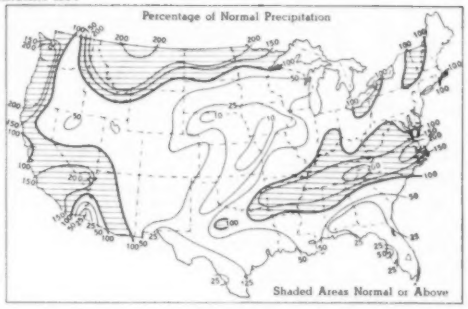
The February pattern showed some marked changes. In the United States there was more amplitude in the north-south waves with a principal ridge over the Plateau and a trough over the Eastern states. Both the low over northeastern Canada and the high over Alaska had pushed westward, so air flow in Canada and northern United States was of Pacific origin and hence mild, dry weather prevailed except on the Pacific Coast. The Great Basin high was the principal feature of the month; it dominated completely for the first ten days and reestablished itself after the 20th. During the last 15 days the trough in central sections gradually deepened and became the scene of the most spectacular storm activity of the winter when Panhandle lows moved northeastward to cause blizzards on the western Plains, dust storms over the southern Plains, line squalls and tornadoes in the South,

A grader clears a path after the 19–22 February 1954 dust storms near Sugar City, southeastern Colorado. Wide World photo.

MONTH OF JANUARY 1954



Departure of Mean Temperature from Normal in degrees Fahrenheit. USWB Chart.



Percentage of Normal Precipitation. USWB Chart.

and eventually heavy snows in the lower Lakes and Appalachians.

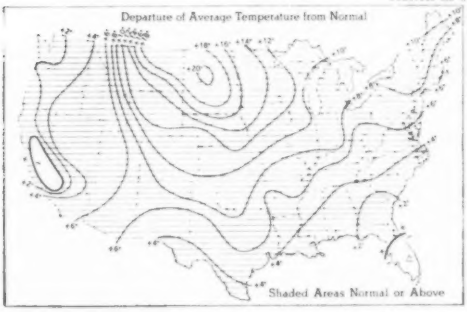
JANUARY—The main weather feature of the first decade of January was a large high pressure cell which appeared over the Mackenzie delta on 2 January and dominated the weather pattern of all Canada for the next ten days. The high, apparently blocked in its normal southeasterly movement, shifted gradually eastward and spread its influence all the way to eastern Canada by the 6th. On the 8th its core was still over western Hudson Bay country, and it was not until midday of the 11th that the center crossed the border into the United States.

Disturbances from the Aleutian low made their way across southern Canada and along the border, each storm taking a trajectory further to the south. Meanwhile the stagnate air in the high over Canada grew colder and colder as the long nighttime radiation removed more and more heat from the air mass, but the heart of the cold air still was contained north of the border. South of the storm track strong westerly flow prevailed, bringing exceptionally warm air from the Pacific eastward in much the same fashion as had occurred throughout December and January. The first week of January averaged 16 degrees above normal in Montana, and it was very warm southeastward in a wide band to Florida.

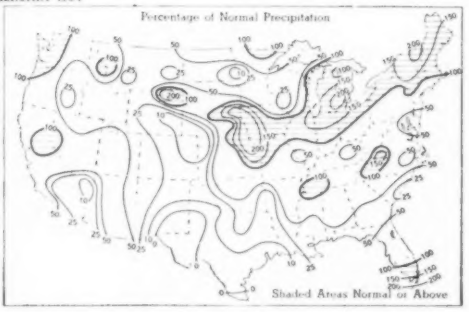
On 7 January a Pacific low moved inland over Washington and sped rapidly southeastward to Iowa by noon of the 8th, and then to Buffalo by the 9th. With cold air poised to the north, it deepened considerably while crossing the interior valleys and developed a complicated frontal system ahead. The cold air plunged southward in the wake of this low, and real winter descended on the northern Plains and the upper Mississippi Valley for a stay that was notable for its duration and severity. Temperatures dropped below zero on the 9th in the North Dakota-Minnesota border areas and the minima at International Falls, Minn., remained at zero or below until 1 February. There were several reinforcements of cold air, the principal ones crossing the border on the 15-16th and the 20th.

The two coldest days at International Falls were the 17th with a minimum of $-40°$ and the 21st with $-41°$, the lowest ever observed at that station since its establishment in 1939. The cold was even more severe in parts of Montana where a reading of $-69.7°$ was reported on the 20th at Rogers Pass (elevation 5470′), on the Continental Divide to the north-northwest of Helena. At Havre, with records dating back to 1880, it was the second longest period of severe cold on record —the mercury did not rise above $-6°$ for 12 days

MONTH OF FEBRUARY 1954



Departure of Mean Temperature from Normal in degrees Fahrenheit. USWB Chart.



Percentage of Normal Precipitation. USWB Chart.

from the 14th to the 26th. This string of consecutive below zero days was exceeded only by the 17-day period, 4–20 February 1936, which was generally the coldest period ever known on the northern Plains. Readings below −50° were reported at other points in Montana, the lowest at a first-order station was −49° at Glasgow on the 20th. Minima below −40° were general in the northern Mississippi Valley on the 20th and 21st; the following state minima were reported: −50° Red Lake Falls, Minnesota; −48° Pembina, North Dakota; −46° Gordon, Wisconsin; and −40° at two stations in South Dakota. At Williston, N. D., in the heart of the new oil district, the mercury read −39° on the 21st, the coldest there since January 1935.

An interesting feature of the cold wave was the very narrow boundary throughout most of the month separating the Arctic air from mild Pacific maritime air over the Plateau region. While spectacularly low readings were holding sway in Montana (the week ending 25 January was 42 degrees below normal at Great Falls), the Idaho–Utah–Colorado area was the center of a very warm section (Boise averaged 10 degrees above normal for the month). Occasionally this warm air descended into the cold valleys of western Montana as is shown by the amazing rise in temperature at Helena under the influence of a southwesterly chinook. The mercury rose from −36° on the 20th to a high of 54° on the 22nd, a rise of 90 degrees in 53½ hours! And from −6 to 54° on the 22nd, a 60-degree change in 24 hours. By the midnight map of the 23rd it was down to −14°.

The cold air pushed out in all directions from its center over the northern Plains, and generated snowstorms all around its fringes. Heavy snows fell in Oregon and Washington at the same time that the East Coast from Virginia northward was experiencing its first general snowstorm since 1948. Though the extreme cold was confined to the northern Plains, the mercury fell below freezing as far south as Corpus Christi, Texas, and readings were as low as −13° on Long Island and in northern New Jersey. The New York area together with the industrial cities of southern New England experienced ten days of real winter weather with deep snow cover and zero readings. The surge of cold air brought the season's lowest readings to the Northeast with the following state minima registered: Maine −35°, Vermont −34°, New Hampshire −31°, New York state −31°.

The weather pattern began to show marked changes by the 26th when the last severe temperatures were registered in the northern Plains. Low pressure aloft moved in from the eastern Pacific and soon established itself over central Canada. On the southerly side of this system strong west winds streamed inland from the Pacific, bringing rebounding temperatures first to the northern Plateau and then to the northern Plains. The cold was in full retreat except in the immediate border areas of North Dakota to Lake Superior, and by the 31st the mercury had climbed above freezing over all the Dakotas and to 60° at Valentine, Nebraska.

FEBRUARY—The last days of January and the first decade of February were dominated by a Great Basin High, which had appeared on the map on the 26th and became firmly established on the 31st. For the next ten days it dominated the weather scene across the United States, bringing daily maxima above freezing to the Northwest, the northern Plateau, and northern border sections. On the eastern slope of the Rockies chinook effects raised the temperature to some unseasonably high readings. It reached 69° at Rapid City on the 3rd and 74° on the 8th, for a new all-time February record. At North Platte in Nebraska a reading of 75° was a new February mark. The week ending the 8th was 27 degrees above normal at Havre and 26 at Bismark where severe winter weather had dominated a few days before. It was also very warm in the southern Plains: Oklahoma City reached 80° on the 9th and Laredo hit 94° on the following day.

Further to the east it was much more seasonable, and in the South with a continued flow of northwest winds it was seasonably cool, as is usually the case with a western ridge-eastern trough regime; temperatures dropped into the low 20's along the Gulf of Mexico on the morning of the 8th. This cold air supplied the energy for a remarkable storm development on a small wave that was over northwestern Florida at noon 7 Feb. The prevailing westerly flow pushed the low to the eastward off the Georgia coast, but once over the Atlantic it received a great store of energy from the warm waters of the Atlantic Ocean and deepened rapidly in the congenial atmosphere of a long polar trough. After threatening the New England coast, the intense cyclone passed northward, deepening to a center pressure of about 950 mb (28.05 inches) when southeast of Nova Scotia. It gave the Maritime Provinces and Newfoundland a terrific lashing. In the wake of the strong pressure gradient created by the storm, a strong flow of northwesterly winds set in over all of Canada and most of the United States east of the Rockies, radiating from a high pressure center of 1053 mb (31.09 inches) over the Yukon on the 10th. A major polar outbreak followed as low pressure persisted in the Atlantic trough and encouraged the southeastward movement of polar air masses. The main impact of the cold air was felt in the Northeast where a very cold and blustery Lincoln's Birthday weekend was experienced. At Burlington, Vt., the maximum on the 12th was only −4°, and it plunged to −22° the next morning. In the ski resorts of New England the press reported readings below −30°. It was generally the coldest weather since January 1952—Boston had its first below zero reading in three winters, and it was below zero in the suburbs of New York City.

The cold spell was of brief duration as southwesterly flow replaced air streams from the north. On the 14th warm air pushed the mercury up to 61° at Washington and to 75° two days later. On that date it was also 75° at Harrisburg and 72° at Hartford, for new all-time February maxima records. Storm centers now entered the United States over the Northwest, but had long trailing troughs and fronts to the Mexican border. Such troughs often induce storm development over the southern Plains; on the 18–19th a marked center of low pressure formed there and moved slowly north-northeastward to the James Bay area of Canada by noon of the 21st.

The circulation set up by this intense storm caused the principal weather events of the month and the major storm of the season over the Great Plains. It has been described by Mr. S. W. Chambers of the Dodge City Weather Bureau:

"The storm moved into the southwestern corner of Kansas during the early morning hours with winds shifting from southerly to northerly and increasing rapidly from the north two to three hours after the shift. Ceilings and visibilities were reduced to zero zero conditions in the dust. Snow began falling shortly before noon, with the intensity increasing rapidly lowering ceilings and visibilities to zero zero during the afternoon. Temperatures ranged from 35 to 25 degrees during and after the snow. Winds reached a peak of 74 MPH, with velocities averaging about 60 MPH for a three-hour period. Snow accumulated to approximately two inches and was drifted into large drifts blocking roads. The snow was accompanied by thunder and lightning.

"Latest reports available indicate three men lost their lives during the storm. The strong winds and dust were reported by the press as the most severe in the last 19 years. Live stock in open fields were widely dispersed, however there were no reports of losses.

"There was a power failure in the city and most of the communication facilities were out from noon Friday to noon Saturday. Weather Bureau personnel on duty at noon Friday remained on duty until Saturday afternoon."

A second frontal system moved inland over the North Pacific states on the 21st, but it did not have a long north-south trough, and as a result, there was no strong cyclogenesis in the southern Plains. A western ridge—central trough—eastern ridge regime became established. It was, however, mild Pacific air that fed into the central trough, as westerly flow over Canada was sweeping pressure systems straight eastward to contain cold air in the Arctic. Storm movement across the United States was around the Basin High in the west and then southeastward into the trough just east of the Mississippi River.

An important development took place during the 27th as a polar trough moved eastward over the Eastern states. The low pressure system slowed down considerably as the Appalachians were reached, and a wave development took place in the Carolina-Georgia area on the trough. Instead of moving northeastward, as South Atlantic lows often do, this storm chose to move northward along the front which was stalled just at the crest of the Appalachians. This was the course followed by the Great Appalachian Storm of November 1950, and some of the weather elements of that memorable occasion were present. Winds in the warm sector approached hurricane speed—a gust of 74 mph was registered at Washington National Airport. Heavy snow fell just to the west of the front. Cleveland had a 15.1-inch fall on the 28th–1st and then more two days later to total 20.8 inches. Further south in Kentucky amounts up to 17 inches were reported in the press. The main ingredient of the 1950 storm, unseasonably cold air, was missing this time with the result that the storm was noteworthy but not outstanding.

Record Low Temperatures

(*Continued from page 26*)

Chief, Instrument Division 16 March 1954

The Weather Bureau minimum thermometer at Rogers Pass, Montana, indicated a value below the lowest line on its scale and the observer described the position of the column relative to the bulb and index. Reproducing that condition in the Laboratory showed that the minimum temperature was at least $-69.2°$F., $+0.2°$F., at the point where the column is level with the top of the index, the latter resting in the bulb. The most probable value is a somewhat lower temperature since the observer reported the liquid to be below the top of the index. A value of $-69.7°$F., $+0.2°$F., was measured at a point where the bore begins to widen which comes closer to fitting the observer's description and is more likely the minimum temperature. It is possible that the temperature may have been lower, but at a lower temperature, the thermometer becomes unreliable for a column height cannot always be reproduced.

CHRISTOS HARMANTAS
Engineering, Upper Air
USWB, Wash., D. C.

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All About the Weather. IVAN RAY TANNEHILL. Random House, New York, 1953. 148 p. $1.95.

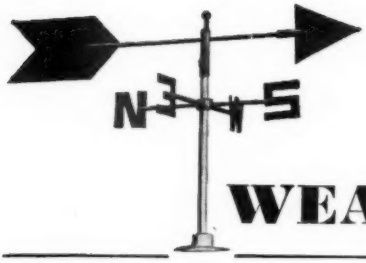
Meteorologists of all degree throughout the country will welcome Mr. Tannehill's latest work, for now there is an authoritative book about the weather for children which can be recommended without reservation to parents and teachers of our science-minded generation. This is another volume in the Random House series of *Allabout Books* designed for readers from age 9 to 12. It is packed full of facts about the science of meteorology and crammed with notes about interesting storms and weather events. Yet all is presented in a simple and effective style, to emphasize that both author and publisher know what they are about. Mr. Tannehill brings in the jet stream, ionosphere, and radar techniques and explains how they fit into the modern weather scene. *All About the Weather* is profusely and appropriately illustrated by Rene Martin. We hope that this fine book will have a wide circulation. It will certainly assist the rising generation in approaching the intricacies of our science and will create a sympathetic understanding of the problems facing the weatherman.

Meteorological Instruments. W. E. KNOWLES MIDDLETON AND ATHELSTAN F. SPILHAUS. University of Toronto Press, Toronto, 1953. Third Edition, Revised. 286 p. $11.50.

The first edition of *Meteorological Instruments* appeared in 1941 and filled a gap in English meteorological literature that long awaited a qualified author. The entire work has now been revised and reset. The main addition has been the inclusion of additional material on instruments used in exploration of the upper-air by means of balloon, aircraft, radio, and radar techniques. The present edition is well illustrated with photographs and diagrams and contains copious footnotes with references. It lacks, however, a good bibliographical discussion at the conclusion. Though the work is intended for the professional weather observer, all who are interested in the weather, regardless of their mathematical or mechanical sophistication, will derive much of interest and value from this useful treatise.

The Climates of the Continents. W. G. KENDREW. Oxford University Press, New York, 1954. Fourth Edition. 607 p. $10.00.

The present edition of this work, first published in 1922, has been revised, enlarged, and entirely reset. Nearly all the climate means have been brought up-to-date, although it went to the press too soon to include the new U. S. Weather Bureau normals. The survey is general in nature, but includes specific sections on each continent. New and interesting material is included on the polar regions.



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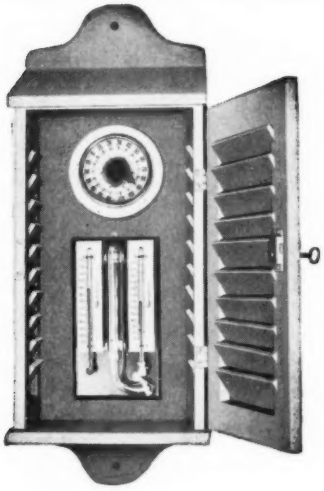

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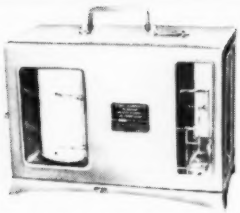

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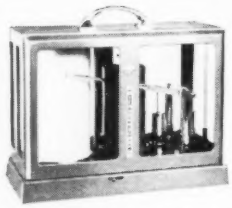

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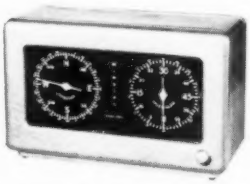

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